A PROVENANCE TRIAL OF PINUS CONTORTA
AT 4,800 FT IN THE KAVEKA RANGE

(Assessment after seven years)

A. CUNNINGHAM AND Q. ROBERTS*

SYNOPSIS

This paper records the establishment of a high-altitude provenance trial of Pinus contorta Doug., and reviews information on survival and growth during the first seven years. The trial is located at an elevation of 4,800 ft a.s.l., which is slightly above the present natural timberline. Eleven seed sources were used of which two were from New Zealand and the remainder from North America. Subspecies represented, on Critchfield’s classification, were contorta, murrayana, and latifolia; of these, subspecies contorta showed the highest growth rates. Survival exceeded 70% for most provenances, but annual height growth was only 1 in. to 4½ in. Plants originating from Karioi Forest (N.Z.) showed satisfactory survival and displayed the greatest vigour.

INTRODUCTION

Pinus contorta is one of the most widely distributed conifers in North America and ranges from 31° N in California to 64° in Alaska, and from the Pacific coast inland to the eastern Rocky Mountains. Altitudinal range is from sea level to 11,000 ft with rainfall variations of 11 in. to over 160 in. It was introduced to New Zealand in 1880; by 1955 more than 20,000 acres had been planted (Weston, 1957).

It is a hardy and vigorous plant and has become established on many difficult sites throughout New Zealand. Seedlings planted at 4,800 ft in the Kaweka Range in 1958 are now well established, and volunteer growth has been reported to over 5,000 ft on Mt. Ruapehu (Tongariro National Park Board, undated publication). Viable seed may be set as early as age 5 (Allsop, 1951); and volunteer growth can be aggressive in the absence of controlling influences such as heavy ground cover or animal browsing. On the Waiouru Military Reserve about 1,000 acres have been “fairly densely” colonized by Pinus contorta and volunteer growth has spread more lightly over a further 32,000 acres (Wardrop, 1964), most of which is land above 3,000 ft altitude. Studies by Benecke (1967) indicated that on grazing land the establishment of Pinus contorta from seed is generally confined to unimproved tussock grassland where carrying capacity is less than one sheep to four acres.

Trial plantings of P. contorta for erosion control in Hawke’s Bay were commenced in 1947 on the Blowhard Plateau

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(Kaweka Range) and during the following 20 years contour plantings became an established practice in the Kaweka Range up to 3,500 ft. The species has also been used elsewhere in the high country for soil conservation work, particularly in the Branch catchment (Marlborough), at Mid Dome (Southland), the Pohangina catchment (Ruahine Range) and in the Rimutaka Range. During the past decade the species has been successfully direct-seeded on certain sites, and helicopters have been used for this work since 1965. In the southern Kaweka and Burns Ranges, several hundred pounds weight are now used annually in direct-seeding operations. Most of this seed is collected from Compartments 8 and 25, Karioi Forest.

Although seeds from a number of different localities were introduced into New Zealand in the early years, the resulting stands are usually referred to as the “green” or “yellow” types, which appear to correspond to coastal and inland origins, respectively (Weston, 1957).

The first formal provenance trial of *Pinus contorta* was established by FRI in 1958 as a preliminary to the 1960-61 studies. A more extensive series of provenance trials with *P. contorta* was established in 1960-61, with 28 seed origins represented. Altitudes of the trials range from 350 ft at Granville to 3,100 ft at Karioi, but most lie between 1,000 and 2,000 ft (Thulin and Miller, 1966).

Stock left over from these trials was offered to the Forest and Range Experiment Station, Napier, for establishment at a high altitude. It was decided to place the trial close to the 5,000 ft level, as in the North Island this is about the upper limit of accelerated erosion problems. In this study, the main concern is with survival and growth rather than with tree form.

**SITE DESCRIPTION**

Selection of a suitable site at the desired altitude was difficult. It required an area of approximately 1 ½ acres, but no such area was available without considerable site variation. The location finally chosen was uniform in slope and reasonably uniform in aspect, but contained two distinct soil and cover types.

The site is a harsh one from 4,800 ft to 4,850 ft a.s.l. on what appears to be a very old scree slope on a south-easterly aspect of Makahu Spur. The slope is uniformly about 38°. About the turn of the century the vegetation was probably induced tussock grassland or subalpine scrub which had been subjected to grazing and possibly burning. It is now fairly stable and clothed with light subalpine scrub and alpine grass species, but slashed in several places towards its eastern portion by runnels of scree. The site is 50 to 100 ft above the present natural timberline which in this region is formed by mountain beech (*Nothofagus solandri* var. *cliffortioides*). Figure 1 illustrates the nature of the site and its cover.

The vegetation lies over a uniform soil type, but where vegetation is absent the surface and subsurface comprise
loose angular rocks with little fine material. Thus, two distinct cover and soil types exist. These are described as follows:

A. Subalpine scrubland 6 to 24 in. tall, dominated by *Chionochloa pallens*, *Senecio bidwillii*, *Podocarpus nivalis*, *Hebe tetragona*, and *Dracophyllum recurvum*, associated with many smaller plants such as *Poa colensoi*, *Anisotome aromatica*, *Wahlenbergia albomarginata*, and *Dacrydium laxifolium*. This cover lies over a uniform but weakly drained soil typically comprising:

- 0-3 in. Dark brown dense mat of fine roots and humic material
- 3-10 in. Dark brown compact silt loam with abundant roots and occasional rocks up to 6 in. diameter merging into:
  - 10 in. + Dark brown loam with occasional roots and abundant angular rocks.

B. No vegetation cover. Surface of loose angular rocks generally 2 to 4 in. in diameter but sometimes exceeding 12 in., and lying over further loose angular rocks varying greatly in size but containing very few fine particles. Air spaces abundant. This profile generally continues beyond a depth of 10 in.
Annual normal rainfall for the plot locality is approximately 130 in. Snow depths of up to 30 in. have been recorded, and the estimated numbers of days per month with snow lying on the site are as follows:

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>3</td>
<td>7</td>
<td>13</td>
<td>29</td>
<td>30</td>
<td>29</td>
<td>17</td>
<td>4</td>
</tr>
</tbody>
</table>

A Sixes max/min thermometer was installed close to the plot and recorded at approximately weekly intervals from 1964 to 1968 inclusive. Data from this instrument should be interpreted with caution but an approximation of the air temperature at the site is as follows:

**Monthly Air Temperatures in °F (averages over 5 years)**

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>68</td>
<td>68</td>
<td>64</td>
<td>57</td>
<td>48</td>
<td>44</td>
<td>45</td>
<td>44</td>
<td>49</td>
<td>56</td>
<td>60</td>
<td>66</td>
<td>55.8</td>
</tr>
<tr>
<td>Min</td>
<td>33</td>
<td>32</td>
<td>34</td>
<td>29</td>
<td>23</td>
<td>22</td>
<td>21</td>
<td>23</td>
<td>22</td>
<td>23</td>
<td>26</td>
<td>29</td>
<td>26.4</td>
</tr>
</tbody>
</table>

The site is exposed to strong winds, particularly from southerly directions. Little or no direct sunshine reaches the site during winter months. The incidence of fog is probably high.

Red and sika deer are present in the locality, but not in high numbers.

**SOURCES OF THE STOCK**

The subspecies classification is that of Critchfield (1957).

**Subspecies contorta**

<table>
<thead>
<tr>
<th>Stock</th>
<th>Code</th>
<th>Altitude</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>56/569</td>
<td>1,250 ft</td>
<td>Compartment 51, Kaingaroa Forest, N.Z.</td>
</tr>
<tr>
<td>Wn</td>
<td>59/342</td>
<td>2,250 ft</td>
<td>Compartments 8 and 25, Karioi Forest, N.Z.</td>
</tr>
<tr>
<td>FRI</td>
<td>56/697</td>
<td>2,000 ft</td>
<td>Six Rivers National Forest, California, U.S.A.</td>
</tr>
</tbody>
</table>

(The two New Zealand seed-lots are considered to have had a common origin in coastal North America, and to be true subspecies contorta; the Californian seed comes from a region where subspecies contorta merges with subspecies murrayana but is more inclined to the former (J. T. Miller pers. comm.).)
Subspecies *murrayana*

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Elevation</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRI 55/510</td>
<td>3,000 ft</td>
<td>Oakridge, Oregon, U.S.A.</td>
</tr>
<tr>
<td>FRI 55/533</td>
<td>3,000 ft</td>
<td>Bend, Oregon, U.S.A.</td>
</tr>
<tr>
<td>FRI 56/693</td>
<td>4,800 ft</td>
<td>Odell Lake Junction, Deschutes National Forest, Oregon, U.S.A.</td>
</tr>
<tr>
<td>FRI 56/694</td>
<td>4,600 ft</td>
<td>Klamath Indian Reservation, Oregon, U.S.A.</td>
</tr>
<tr>
<td>FRI 56/695</td>
<td>3,700 ft</td>
<td>Foster Ck., Oregon, U.S.A.</td>
</tr>
<tr>
<td>FRI 56/702</td>
<td>8,000 ft</td>
<td>Stanislaus National Forest, California, U.S.A.</td>
</tr>
</tbody>
</table>

Subspecies *latifolia*

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Elevation</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRI 53/172</td>
<td>4,000 ft</td>
<td>50 miles N.E. of Jasper, Alberta, Canada.</td>
</tr>
<tr>
<td>FRI 54/325</td>
<td>3,000 ft</td>
<td>Robbins Range, Kamloops Forest District, British Columbia, Canada.</td>
</tr>
</tbody>
</table>

**NURSERY HISTORY**

All stock was raised in the FRI nursery and transferred to the area just prior to planting, except Wn 59/342, which was raised in Makahu Saddle nursery. At the time of planting, all the North American stock was age 4, and the New Zealand seed-lots were 3 years old.

**ESTABLISHMENT**

Most of the trial (40 plots) was established in June 1962. Two further plots and a “buffer” surround were planted in October 1962. Weather conditions at the times of planting were good (i.e., neither dry nor windy), and the condition of the stock was, in general, satisfactory. The trial area is rectangular and contains 42 plots each 24 ft × 30 ft and containing 20 trees at 6 ft × 6 ft spacing. A simple randomized design replicated the eight main provenances five times. Two additional provenances (55/533 and 56/694) were established as single plots only. The buffer surround consisted of a separate provenance (59/342). Blanking was carried out in 1963 and 1964 on all provenances except the surround. Details are provided in Table 1.

At the time of planting, all trees were described as being sturdy with well developed stem and root systems. Moisture condition of the roots was satisfactory in all cases except for 55/533, 56/694, and 54/325, where a slight degree of dryness was noted. Slight foliage wilting was recorded for 53/172, 54/325, 56/569 and 56/693. The foliage of 56/702 was noted as being slightly chlorotic.

**FIELD ASSESSMENTS**

The plots were examined in the spring and autumn of the first two years after planting, following which summer or autumn inspections were made annually. At each inspection,
TABLE 1: SURVIVAL PERCENTAGE ON THE FOLLOWING DATES

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Subspecies Contorta</th>
<th>Subspecies Murrayana</th>
<th>Subspecies Latifolia</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRI 56/697</td>
<td>R 56/569 100 157 71 45 43 52 50 48 39 39 38 37</td>
<td>FRI 55/510 100 112 96 91 88 89 86 85 85 85 85 82</td>
<td>FRI 55/172 100 131 92 84 84 73 74 69 67 67 66 63</td>
</tr>
<tr>
<td>Wn 59/342</td>
<td>242 242 93 91 89 83 81 78 78 75 75 73</td>
<td>20 25 80 75 75 80 76 76 72 72 72 72</td>
<td>100 103 98 97 97 96 96 94 94 94 94 91</td>
</tr>
<tr>
<td>FRI 56/697</td>
<td>100 118 97 89 85 83 83 78 64 63 63 58</td>
<td>20 21 100 95 95 95 95 90 90 85 85 76</td>
<td>100 109 97 95 95 91 89 83 83 83 83 79</td>
</tr>
</tbody>
</table>

(Minor increases in survival percentage are due to blanking)
survivals were recorded and an ocular estimate was made of height. After four years it became apparent that estimated heights were not providing sufficiently accurate information, and, in March 1967, individual tree heights were measured. A similar measurement was made in late February 1969. (Phenology studies of *P. contorta* in the vicinity indicate that annual height increments cease by the end of February.) Observers were also required to note any damage by animals.

RESULTS

An analysis of variance was applied to determine the influence of the two distinct cover and soil types on survival and on total height. Provenances 55/533, 56/694, and 59/342 were excluded from this analysis because they were not fully replicated. The analysis showed that, for the replicated provenances, the influence of site was negligible.

Survival of the various provenances throughout the seven-year period is presented in Table 1.

Table 2 presents estimated mean height of the trees at time of planting, measured tree heights at ages five and seven, and mean annual increment between ages five and seven.

No browsing or bark chewing was recorded, but a small amount of damage from antler rubbing was noted.

DISCUSSION OF RESULTS

Survival

The ability of plants to survive on difficult mountainland sites is of fundamental importance, and the fact that for most provenances survival exceeded 70% after seven years emphasizes the suitability of *Pinus contorta* for high-altitude work.

The satisfactory survival of plants from the Karioi seed source should particularly be noted, as this provenance is at present being widely used for high country work in the North Island.

Plants originating from Kaingaroa seed gave poor survival. In view of the probable common origin of the Karioi and Kaingaroa seed-lots the difference in survival is surprising. The two lots were three years old at planting and both were described as sturdy with well-developed root systems. The difference between the two lots was that the Karioi stock was raised at Makahu nursery and averaged 9 in. tall at planting, whereas the Kaingaroa stock was raised at FRI nursery and was 14 in. high at planting. This suggests that the low survival of the Kaingaroa stock could be related to lack of acclimatization and/or tree-height at time of planting. The lack of acclimatization was shared with all other seed-lots except the one from Karioi. It is probably important that trees be not too tall at time of planting. The only two seed-lots whose estimated mean height at planting exceeded 12 in. (R 59/569 and FRI 56/697) were also the ones which showed lowest survival. No firm statistical relationship, however,
### TABLE 2: MEAN HEIGHT AND INCREMENT IN INCHES

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Measured Estimated Height at Height</th>
<th>Measured Height</th>
<th>7jr</th>
<th>Annual Height</th>
<th>Increment (1967-1969)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subspecies contorta</td>
<td>Height at planting (14/3/67)</td>
<td>14</td>
<td>24.7</td>
<td>30.9</td>
<td>3.1</td>
</tr>
<tr>
<td>R 56/569</td>
<td>9</td>
<td>21.8</td>
<td>30.6</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Wn 59/342</td>
<td>18</td>
<td>31.1</td>
<td>35.2</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>FRI 56/697</td>
<td>9</td>
<td>25.4</td>
<td>30.1</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Subspecies murrayana</td>
<td>FRI 55/510</td>
<td>10</td>
<td>22.4</td>
<td>27.0</td>
<td>2.3</td>
</tr>
<tr>
<td>FRI 55/533</td>
<td>8</td>
<td>23.5</td>
<td>28.0</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>FRI 56/693</td>
<td>8</td>
<td>19.4</td>
<td>22.9</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>FRI 56/694</td>
<td>9</td>
<td>22.5</td>
<td>26.1</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>FRI 56/695</td>
<td>6</td>
<td>16.3</td>
<td>18.3</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>FRI 56/702</td>
<td>9</td>
<td>20.5</td>
<td>24.2</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Subspecies latifolia</td>
<td>FRI 54/525</td>
<td>8</td>
<td>26.3</td>
<td>30.5</td>
<td>2.1</td>
</tr>
</tbody>
</table>

could be established between tree height at time of planting and survival, when all provenances were considered.

Examination of the overseas provenances indicated no clearly defined correlation between survival and altitude of seed source, or between survival and latitude of seed source. Such relationships may nevertheless be revealed by more intensive studies.

**Growth**

An important feature of the study is the very limited annual height increment (1.0 to 4.4 in.) which occurs on this site. It should be noted that the site is on a cold south-easterly face; higher growth rates could be expected on northerly aspects with comparable soils.

The second point of interest is that the highest increments occurred on the provenances of New Zealand origin, both of which are regarded as belonging to the subspecies *contorta*. Seed from Karioi produced the most vigorous trees, and although these were planted as a surrounding buffer, it is thought that edge effect would have little influence at this stage.

Growth rates of subspecies *contorta* (3.2 in. annually) exceed growth rates of subspecies *latifolia* (2.0 in.) and *murrayana* (1.9 in.).

Amongst the overseas provenances, there appears to be a tendency for the tallest trees, at age 7, to be derived from the seed sources of lower altitude. This correlation between tree height and seed source is significant at 10%.

A stronger relationship appears to exist between tree height at time of planting and tree height at age 7. Provenances
which were taller at planting retained their height lead after
seven years. \((r = 0.870 \text{ for } n = 11; \text{ sig. } 0.001\%)\).

Animal Influence

There was nothing to suggest that animals of any sort
influenced survival of the plants. Antler damage was very
light — this is to be expected, as experience in the region
suggests that the critical period for antler rub will occur
when the trees are between 3 ft and 5 ft tall.

CONCLUSIONS

The trial is not wide enough in range nor sufficiently ad­
vanced to provide firm recommendations regarding the most
suitable overseas seed source for high-altitude planting, but
there is some evidence to suggest that the best seed may
prove to be from relatively low altitudes. Of the three sub­
species, *contorta* appears to be superior to both *murrayana*
and *latifolia*.

The study indicates that seed from Compartments 8 and 25,
Karioi Forest, is well suited for use in this class of high coun­
try. Plants should not exceed 12 in. in height for establish­
ment on hard sites.

Finally, the trial shows that on cold high-altitude sites,
growth rates of only a few inches per year can be expected.

ACKNOWLEDGEMENTS

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ing and assessment work was sometimes carried out in bitter
weather conditions, for which work thanks are due to G. N.
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their assistance with the paper and interpretation of the data.

REFERENCES

Allsop, F., 1951. First production of fertile seed by the principal exotic
Anon (undated). *Alien Pines or Native Tussock in Tongariro National
Park.* Tongariro Nat. Park Bd.
& Mountainlands Rev.* No. 13.
Critchfield, W. B., 1957. Geographic variation in *Pinus contorta.* *Maria
Thulin, I. J.; Miller, J. T., 1966. Provenance trials of *Pinus contorta* —
Establishment report. *Forest Tree Improvement Rep.* No. 24. *N.Z.*
Forest Service (unpubl.).
contorta on the Waiouru Military Reserve.* *N.Z. For. Ser.* (unpubl.
rep.).
Wellington.*
THE PHOSPHATE STATUS OF THE SOILS OF RIVERHEAD FOREST IN RELATION TO GROWTH OF RADIATA PINE

R. BALLARD*

SYNOPSIS

An investigation of the relationships between soil phosphorus (P) levels, and foliar P levels and productivity of 40-year-old radiata pine stands at Riverhead Forest showed that:

(a) Productivity throughout the forest is limited by inadequate available soil P.

(b) Soil P extracted by some chemical soil tests is as closely related to productivity as is foliar P.

(c) Soil chemical tests which remove readily exchangeable phosphate from the soil (Olsen, Bray No. 2 exchange resin) provide the best reflection of the soil P status for radiata pine. Tests for total P were suitable only when considered within groups of soils having similar properties.

INTRODUCTION

The response of radiata pine (Pinus radiata, D. Don) to phosphatic fertilizers at Riverhead Forest is well documented (Weston, 1956, 1958; Conway, 1962; Will, 1965; Mead, 1968). A preliminary study on soil phosphorus (P) levels at Riverhead by Ballard (1969) showed that inadequate levels of extractable inorganic phosphate in the topsoil appeared to be limiting the productivity of pine stands. This paper reports the results of an appraisal of different methods of estimating the P status of Riverhead soils.

Plant tissue analysis and soil analysis are the two most common methods of evaluating site nutrient status. In forestry, the emphasis has been on the use of tissue analysis, the diagnostic value of which has been reviewed and discussed in recent literature by Viro (1961), Tamm (1964), Qurestri and Srivastava (1966), Raupach (1967) and Leaf (1968). The interpretation of tissue analysis results is based on the assumption that tissue concentrations reflect the soil nutrient status. However, luxury consumption, ion interaction, growth and translocation effects, and the varying influences of environmental factors may invalidate such an assumption. Leyton and Armson (1955) suggest that difficulties of interpretation resulting from luxury consumption and ion interaction could, to a certain extent, be avoided by extending the in-

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